General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

X-693-71-267
PREPRINT

NASA TM X-65637

NOTE ON THE CHARACTERISTICS OF SUN SPOT GROUPS WHICH PRODUCE SOLAR PROTON FLARES

KUNITOMO SAKURAI

JULY 1971

GSFC
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

NOTE ON THE CHARACTERISTICS OF SUNSPOT GROUPS WHICH PRODUCE SOLAR PROTON FLARES

by

Kunitomo Sakurai*
Radio Astronomy Branch
Laboratory for Extraterrestrial Physics
NASA, Goddard Space Flight Center
Greenbelt, Maryland 20771

ABSTRACT

Solar proton flares are associated with sunspot groups which show an unusual distribution of magnetic polarities. Furthermore, the gradient of the magnetic field is very large before the onset of these flares. The importance of polar cap absorptions, which is proportional to the integral flux of solar cosmic rays, tends to increase as the gradient of the magnetic field becomes greater. It is shown that the formation of such gradients is associated with the rotating motion of sunspot groups. Hence, the sunspot groups which show a reversed polarity distribution are very effective for the production of solar proton flares.

*NASA Associate with University of Maryland

It has been thought that the mechanism of solar flares is closely related to the configuration of sunspot magnetic fields (e.g., Severny, 1964, 1965; Warwick, 1966). The formation of the neutral region in sunspot groups and its relation to the gradient of the magnetic fields appears to be very important for the triggering of flares.

Severny (1965) has studied the relationship between the gradient of sunspot magnetic fields and the characteristics of solar proton flares. He classified flares into four classes which are related to the gradient of sunspot magnetic fields. The first two classes (I and II) are associated with the generation of solar cosmic rays, but the magnitude of flares seems to be greater for class I than for class II flares. The gradient of sunspot magnetic fields of class I is greater than that of class II on the average.

In this paper, we first examine the relationship between the gradient of sunspot magnetic fields and the importance of polar cap absorptions (PCA's) by using the observational data by Severny (1965) on those gradients before the beginning of solar flares. The importance of PCA's has been taken from the data compiled by Obayashi et al. (1967). The result is shown in Fig. 1. In this figure, we show the histogram of the importance of PCA's for the two classes of solar flares (I and II) which was defined by Severny (1965).

The importance of PCA's for the solar flares of Class I is almost 3 and 3+, whereas that for the flares of Class II is mainly 2. Consequently, our result indicates that PCA's of greater importances are associated with sunspot magnetic fields whose gradient is relatively greater. This means that the magnitude of the gradient of sunspot magnetic fields tends to become greater as the importance of PCA's increases. In fact, if we plot the magnitudes of these gradients with respect to the importance of PCA's, we obtain the result as shown in Fig. 2. This result shows that the importance of PCA's tends to become greater with the gradient of the magnetic fields. This is important in considering the mechanism of solar proton flares because some characteristics of such flares seem to be essentially controlled by the gradient of magnetic fields before the onset of the flares.

Recently, the rotating motion of sunspot groups which produce proton flares has been discovered (Sakurai, 1967, 1969; Sawyer and Smith, 1970; McIntosh, 1969, 1971). This motion is counterclockwise (clockwise) in the northern (southern) hemisphere of the sun. Due to such a motion, the magnetic polarity distribution of sunspot groups becomes very unusual and sometimes opposite to the general pattern observed in sunspot groups which are not associated with proton flares (Sakurai, 1967).

Sakurai (1967, 1969) has obtained two characteristic types of the polarity distribution on sunspot groups which were associated with proton flares. They are shown in Fig. 3 and defined as Type I and II, respectively. Sunspot groups of type I move their polarity distribution reversed from those of most sunspot groups: the polarity which must be accompanied by the forgoing spots is seen over the following portion of sunspot groups. This suggests that the polarity distribution of such spot groups must have been reversed as a result of their counterclockwise motion in the northern hemisphere. Such motion was, in fact, observed in case of sunspot groups which appeared in March-April, 1960 (Ellison et al., 1960) and May, 1967 (McIntosh, 1969). On the other hand, sunspot groups of type II do not show such reversal of the polarity distribution, but their magnetic axes are already oriented in the northern hemisphere to NE-SW direction due to this rotating motion. This orientation is certainly related to the counterclockwise motion of sunspot groups (e.g., Sawyer and Smith, 1970). These situations are all reversed in the southern hemisphere.

The numbers of solar proton flares of classes I and II observed by Severny (1965) were fourteen and nine, respectively.

According to our analysis, all but one of these proton flares of class I were produced from sunspot groups of type I. While, the eight cases of proton flares of class II were associated with sunspot groups of type II.

This result shows that the importance of PCA's, i.e., the integral flux of solar cosmic rays (Smart and Shea, 1970), is closely dependent on the configuration of sunpot magnetic fields. As has been suggested by Sakurai (1970), the counterclockwise (clockwise) motion of sunspot groups in the northern (southern) hemisphere may be accompanied by the storage process of flare energy. The gradient of magnetic fields may be responsible for the effectiveness of flare energy release and its relation to acceleration of high energy particles.

In this paper, we have shown that the sunspot groups of type I and II are mainly associated with proton flares of class I and II, respectively. This result indicates that the configuration of the sunspot magnetic fields which are strongly twisted counterclockwise (clockwise) in the northern (southern) hemisphere is effective for the production of solar proton flares. We suggest this evidence must be considered in the study of the mechanism of solar flares and associated acceleration process of solar cosmic rays. It must be remarked that many of the sunspot groups studied here were associated with the loop prominence systems after the end of the flares (Bruzek, 1964). The formation of such systems may also be connected to the configuration of sunspot magnetic fields as mentioned above.

REFERENCES

Bruzek, A., 1964: Optical characteristics of cosmic-ray and proton flares, J. Geophys. Res., 69, 2386-2387.

Ellison, M.A., McKenna, S.M.P. and Reid, J. H., 1960: The solar flare of 1960 April 1, Observatory, 80 149-152.

McIntosh, P.S.. 1969: Sunspot associated with the proton flare of 23 May, 1967, WDC A Rept. UAG-5, 14-19.

McIntosh, P.S., 1971: Lecture at NRL, Washington, D.C., April 19.

Obayashi, T., Sakurai, K., Hakura, Y., Nishida, A., Kai, K., Yoshida, S., Wada, M. and Yamamoto, M.,1967: Table of solar geophysical events, Jan. 1957-Dec., 1963, Kyoto University.

Sakurai, K., 1967: Solar cosmic-ray flares and related sunspot magnetic fields, Rep. Ionos. Space Res. Japan, 21, 113-124.

Sakurai, K., 1969: Magnetic structure of sunspot groups which produces solar proton flares, J. Geomag. Geoel., 21, 463-470.

Sakurai, K., 1970: On the magnetic configuration of sunspot groups which produce solar proton flares, Planet. Space Sci., 18, 33-40.

Sawyer, C. and Smith, S.F., 1970: Preceding change in the active region, WDC A Rept UAG-9, 9-12.

Severny, A.B., 1964: On the behavior of magnetic fields associated with solar flares, in AAS-NASA Symp. Physics of Solar Flares, NASA Sp-50, ed. by W.N. Hess, 95-101.

Severny, A.B., 1965: On the change of magnetic fields connected with flares, in Stellar and Solar Mag⁻etic Fields, 358-368, ed. by R. Lüst, North-Holl. Pub., Amsterdam.

Smart, D.F. and Shea, M.A., 1970: Proposed solar proton event classification system,in Intercorrelated Satellite Observations Related to Solar Events, 102-107, ed. by V. Manno and D.E. Page, D. Reidel, Dordrecht.

Warwick, C.S., 1966: Sunspot configuration and proton flares, Ap.J., 145, 215-223.

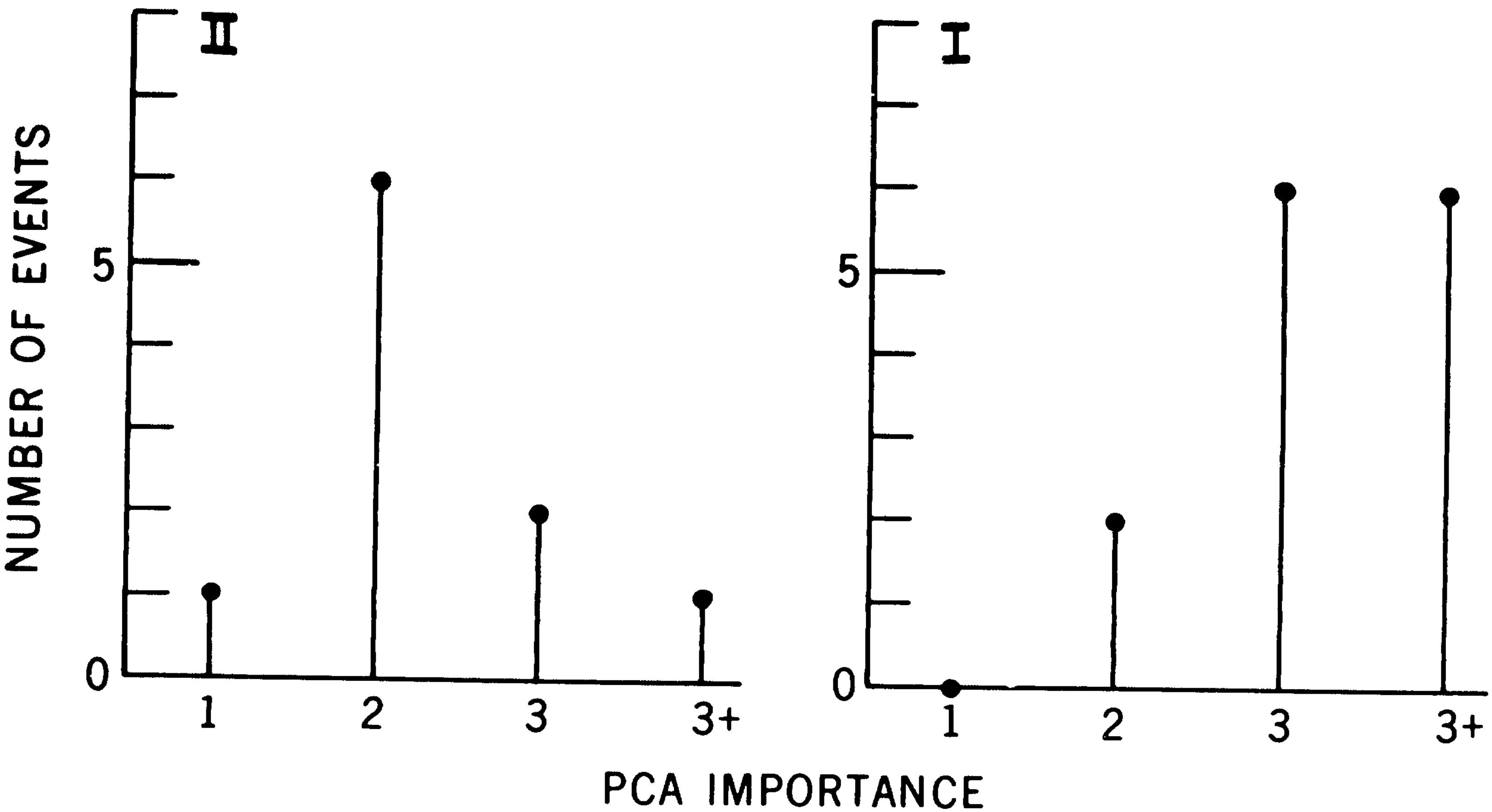
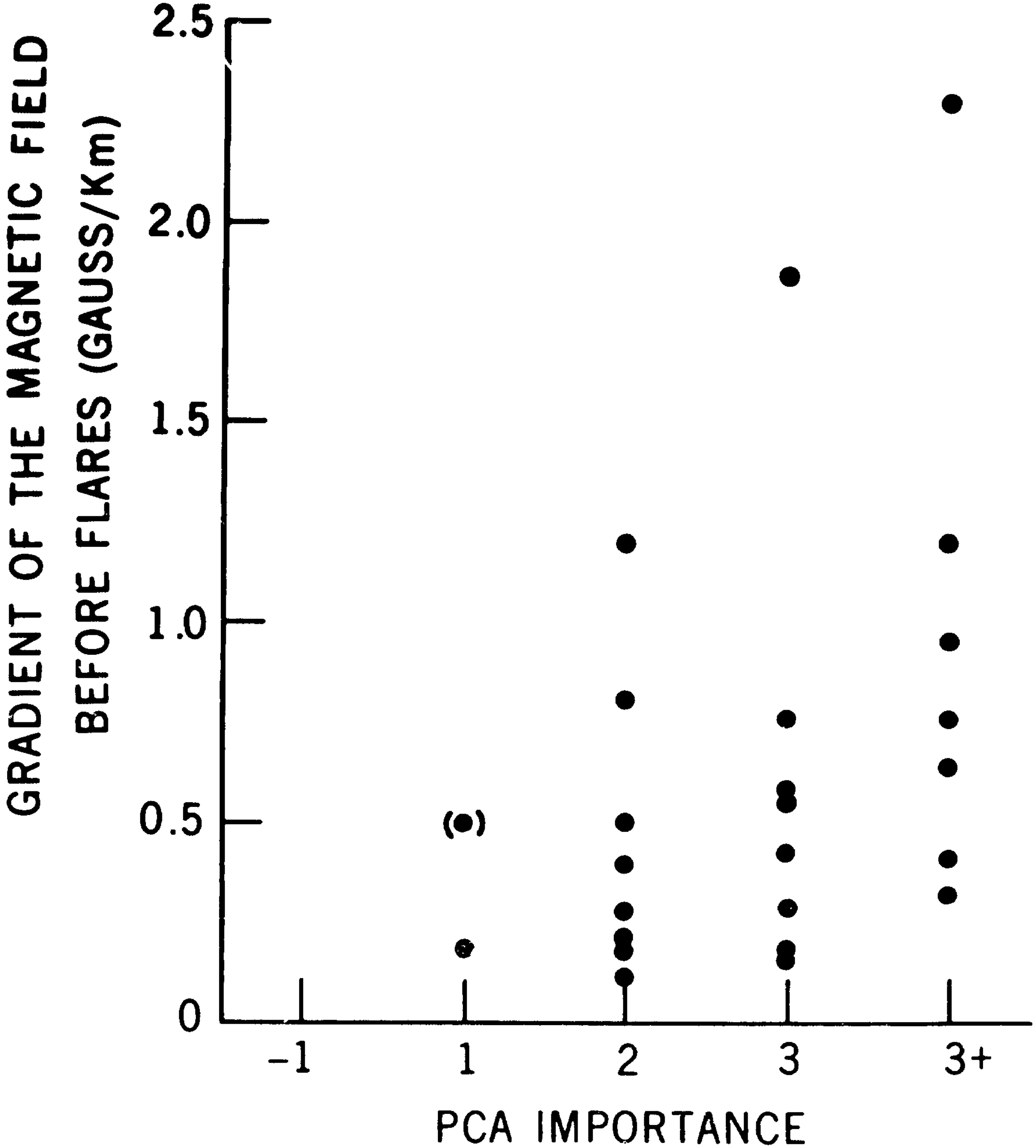


Figure 1. The histogram of the importance of PCA's for the two classes of solar flares (I and II).

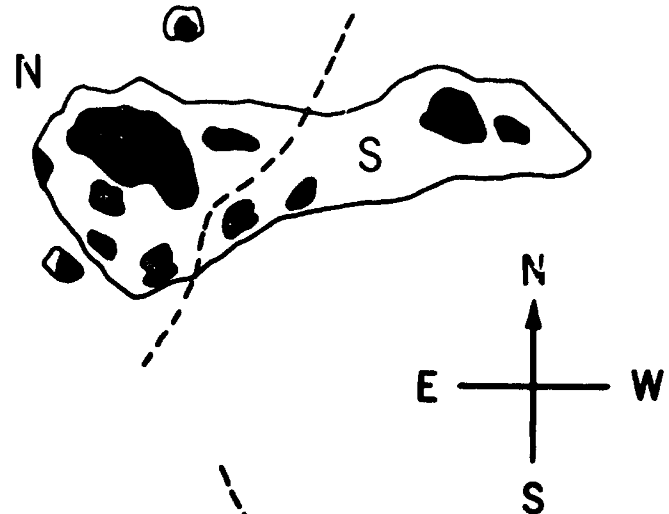

GRADIENT OF THE MAGNETIC FIELD
BEFORE FLARES (GAUSS/Km)
2.5
2.0
1.5
1.0
0.5
0
-1
1
2
3
3+
PCA IMPORTANCE

MAGNETIC FIELD DISTRIBUTION OF SUNSPOT GROUPS WHICH PRODUCED PROTON FLARES IN THE NORTHERN HEMISPHERE

TYPE I

JULY 7, 1958

SUNSPOT GROUP
NUMBER 13356



TYPE II

SEPTEMBER 20, 1963

SUNSPOT GROUP
NUMBER 15768